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To: Mr. D. Austin
Commissioning Manager
Pickering NGS

SHAFT ACCELERATION DETECTORS - PICKERING NGS COMMISSIONING TEST RESULTS FOR UNIT 2

R. E. Beaulieu

Shaft Acceleration Detectors have been installed on Pickering NGS units 1 to 4 to replace auxiliary governors which have been shown to be unacceptable from a power system stability aspect. The new detectors are now in service on all units. The Electrical Research department was requested to assist station personnel in the commissioning of this equipment. A previous report covered the commissioning work for units 1, 3 and 4. This report provides the commissioning test results for unit 2.

1.0 INTRODUCTION

References 1 to 6 describe the shortcomings of the original Auxiliary Governors and the modifications to the Shaft Acceleration Detector, (SAD), carried out before the equipment went into service. Reference 5 describes all the details of the modifications. The Shaft Acceleration Detectors are required on Pickering units 1 to 4 to handle situations where more than 50% of the generator load is suddenly rejected. Under such circumstances, the existing mechanical governor alone is unable to maintain the turbo-generator speed below the setting of the overspeed trip bolts. The action of the acceleration detector on the steam valves is essentially duplicated by a pallet switch on the switchyard breaker if the load rejection is caused by local breaker operation, but if the local breaker does not open, as could be the case for a system fault close to Cherrywood, then the acceleration detector function is required. The detectors were installed on unit 1 when it was re-commissioned in 1987, and on units 3 and 4 when they came down for major outages in 1987. The detector was installed and commissioned on unit 2 when this unit returned to service in late-1988. This report describes the commissioning test results. The commissioning procedure followed to verify this equipment prior to placing it in service is included in an appendix.

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2.0 NAMING CONVENTION

To avoid confusion with acronyms for the existing Electric Anticipatory Device (EAD) and the initial designation of Electronic Acceleration Detector Device (EADD), the term Shaft Acceleration Detector (SAD) will be used in this report. This naming convention is now in use at the station.

3.0 MAJOR TESTS PERFORMED DURING COMMISSIONING

The commissioning work is divided into four major parts. The first part includes the verification of the wiring with the equipment de-energized, to ensure that the revisions to the wiring have been carried out properly and the additional equipment has been installed as per drawings.

The second part is a static check of the power supplies, the individual module test points, etc, with simulated speed and generator terminal voltage signals.

The third part of the tests measures the dynamic performance of the Shaft Acceleration Detector, using programmable function generators to simulate shaft acceleration of different magnitudes.

The fourth part of the commissioning tests consisted of monitoring the performance of this equipment during genuine load rejection tests on unit 2, performed as part of the unit recommissioning.

4.0 TEST RESULTS

4.1 Wiring and Installation Checks

Since the wiring was extensively modified, it was necessary to do a wire by wire check of the cubicle. In addition, all the wiring for incoming and outgoing signals was verified all the way back to where the signals are obtained or used. Control Maintenance staff at the station performed most of this work. As a guide in this part of the commissioning process, revised drawing NA44-EMG-64117-1086, included in the revised equipment manual, was used.

4.2 Static Tests

Using a function generator to simulate the three speed probe signals, a complete check of all the electronic modules was performed per the commissioning procedure in the appendix. Test point signals were compared to theoretical values, offsets in circuits were adjusted as required and power supply voltages were measured on all modules and redundancy checks were done.

4.2.1 26-Volt Power Supplies Voltages

Power supply number 1:	+26V bus:	+28.33V dc
	-26V bus:	-28.32V dc
Power supply number 2:	+26V bus:	+28.54V dc
	-26V bus:	-28.53V dc

4.2.2 Test Point signals

Values in the table below were obtained with a speed signal of 480 Hz feeding all three channels.

	CH. 1	CH. 2	CH. 3
TP1	+15.2V	+15.30V	+15.31V
TP2	-15.10V	-15.07V	-15.11V
TP3	COM	COM	COM
TP4	*	*	*
TP5	PULSE	PULSE	PULSE
TP6	0	0	0
TP7	0.77V	0.92V	1.00V
TP8	-8.36V	-8.35	-8.33
TP9	-0.08V	-0.07V	-0.05V
TP10	-0.11V	0.01V	0.01V

* Signal on TP4 is a 480 Hz clipped sinewave with a peak-to-peak amplitude of 0.5V, representing the signal at the input junction of an operational amplifier.

4.2.3 Operating Levels of RXIB Relay

The RXIB2 overcurrent relay receives its signal from a voltage-to-current circuit formed by filter RXTBEB4 and loading resistor RXTDA1. The three phase voltage signal at the input to the filter was varied to obtain the operate and dropout levels for the overcurrent relay.

Contact closes at: 113.4 V line-line
Contact opens at: 97 V line-line

4.2.4 Verification of the Logic

The operation of indicator lights, local and remote alarms, local and remote reset switches and computer message were all verified to ensure correct operation. Deficiencies were corrected as required, except for the "SAD Operation" indication to the control room which was to be repaired under a DR (Deficiency Report). Verification of the 2-out-of-3 logic was done during the dynamic tests.

4.3 Dynamic Tests

Dynamic performance tests were carried out to demonstrate that the acceleration detectors did not operate with a 4.4% per second simulated acceleration, but did so with an acceleration of 4.7% per second or greater, Figure 1. The nominal setting of each module is 4.5% per second. Figure 1 shows that the calibration of TP10 on each module is slightly different. Channel 1 has a calibration of 1 volt=2.11%/s, channel 2 is 1 volt=1.82%/s and channel 3 is 1 volt=1.86%/s. This difference in calibration is offset by the setting on the acceleration level detector, resulting in all modules operating at essentially the same point. With generator terminal voltage at less than 85% of rated value, the operating time, measured from the time speed begins to change to the time the output contacts operate is 360 milliseconds with 5%/s acceleration. With the

generator terminal voltage at rated value, the time delay in the output signal is effectively bypassed and the operating time measured under those conditions is 240 milliseconds, per Figure 2. Figure 3 shows that the RXKB timer operates in 150 milliseconds.

Tests were performed to demonstrate that the operation of any two channels would operate the logic correctly but the operation of a single channel would not be sufficient to issue an output signal.

Power supply failures were simulated to demonstrate that the equipment operates correctly with only one supply in service. A supply failure is detected by the alarm logic.

The output seal-in timer was set and verified at 11 seconds, Figure 4. After the completion of the commissioning work on units 1, 3 and 4 it was decided to set this timer at 11 seconds and remove relay R13 contacts from service. [8,9]

Operation of the alarm logic was checked for loss of power supply, operation of one or more channels and loss of the speed signal in one or more channels.

Tests were performed on the On-Load Test Module to verify its calibration. Figure 5 shows the speed signal acceleration on test point 10 of channel 1 for simulated acceleration of 6% per second using a programmable function generator and then for a simulated acceleration using the On-Load module. These results show that this module simulates a 6%/s acceleration. The interlocks in the On-Load module test switches prevent the simulated speed signal from reaching more than one channel at a time.

During the course of the commissioning tests on unit 4, and also during load rejection tests on unit 1, it was discovered that test points 9 and 10 on the speed detector modules were very sensitive to any capacitive load connected to them. The capacitance in 3 metres of recorder lead was enough to cause the operational amplifiers to oscillate and produce an output signal from the logic. The addition of a 10 kilohms resistor internally, in series with the test point jack eliminates this problem. Station personnel have modified unit 2 modules to add this resistor to test points 9 and 10.

4.4 Unit-Operating Measurements

When unit 2 turbogenerator was returned to service, the speed probe signal to all three channels was checked. A signal of 30 volts peak-to-peak was measured. The minimum acceptable level is 8 volts, zero-to-peak. A speed probe gap of 0.03 to 0.05 inch is required to obtain this signal. With the turbogenerator at 1800 RPM, all the test points signals were measured and compared to theoretical values.

With the generator running on open circuit, at rated speed and rated terminal voltage, the voltages on TB-B terminals 1, 2 and 3 were measured to ensure that the generator voltage was reaching these terminals. The correct phasing of the terminal voltage signal to this equipment is checked by measuring a voltage of 36 volts on TB-C terminals 6 and 7. With a terminal voltage of 113 volts secondary, the signal on TB-C6 and 7 is 33 volts.

At 85 MW gross power, the test point signals were measured and the following results obtained:

	CH. 1	CH. 2	CH. 3
TP1	+15.28V	+15.34V	+15.35
TP2	-15.14V	-15.16V	-15.12V
TP3	COM	COM	COM
TP4	*	*	*
TP5	PULSE	PULSE	PULSE
TP6	0	0	0
TP7	-	-	-
TP8	-8.373V	-8.344	-8.36
TP9	+0.176V	-0.122V	-0.163V
TP10	+0.087V	-0.320V	0.014V

It will be noted from the above measurements that the dc offset on test points 9 and 10 has increased from the values obtained during commissioning. It may be necessary to re-adjust the dc offsets after this equipment has been in service for a few months. Similar equipment on the governor system of the B-side units also displayed a similar problem.

4.5 Load Rejection Tests

While conducting load rejection tests on unit 2, as part of the overall unit re-commissioning, the shaft acceleration detector was monitored with a six-channel direct-writing recorder. Results for 25%, 50%, 75% and 100% load rejection tests are presented in Figures 6 to 12. The detectors do not operate at all for the 25%-load and the 50%-load tests. On unit 1, at 50%, the detectors operated momentarily because the MW loading on the unit was slightly higher. For a load rejection of 75%, initiated by operating a breaker at Cherrywood TS, the detectors operate as expected, with a measured operating time of 160 milliseconds, Figure 9. The output seal-in timer resets 12 seconds after initiation of the load rejection.

For both the 75% and 100% load rejections, acceleration remained above the detector set point for approximately 1.5 seconds, per Figures 9 and 11. The seal-in timer then holds the final output signal for an extra period of time equal to the timer setting, per Figure 9.

Figures 6, 7, 8, 9 and 11 show that there is a significant amount of noise in the acceleration signal immediately following a load rejection. This noise is the result of high torsional components in the speed signal, generated by the load rejection disturbance. The acceleration detector circuits extract the rate-of-change of the speed signal to obtain acceleration and hence torsional components, after differentiation, appear like high instantaneous acceleration components. Notch filters in these modules reduce the "noise" level to an acceptable value and the detectors do not operate for load rejections of less than 50%. [5]

Figures 10 and 12 show the shaft speed obtained during the 75% and 100% load rejection tests. This speed signal was obtained from an independent electronic circuit, using one of the probes feeding the acceleration detector. Even with significant filtering in the signal, a large noise component is produced in the output. For the 75% test, only two spurious pulses are produced but for the 100% test the noise component is very high. Interference from relay operation was ruled out. One logical explanation could be that the probes are very close to the shaft and immediately following the load rejection the shaft comes close to the probe, distorting its output signal. It is interesting to note that immediately prior to and immediately following the tests, the signal is very clean. Also, the speed signal in the acceleration detector equipment remains clean. The differences between the two speed signals could be explained by the different

methods used to derive the dc signal proportional to speed in the SAD equipment and the equipment used to obtain the speed trace of figures 10 and 12. In the SAD circuits, the zero crossings of the speed pulses are used as trigger point whereas a 4.5 volt threshold detector is used in the independent speed signal circuit.

It is recommended that the gapping of all three probes be checked at the next major outage.

4.7 Performance on unit synchronization

When the operators synchronized unit 2 prior to the 75% load rejection test, the SAD operated to close the ESV, the intercept and governor valves. This "spurious" operation was investigated and measurements taken when the unit was synchronized after the 75% test. Figure 13 shows that when using the auto-synchronizer the unit speed is at 1808 rpm just prior to closing the breaker. This results in a large speed swing on the unit, with severe torsionals, and the instantaneous acceleration on the return swing is approximately 4.5%/s, the value at which the SAD is set to operate. On this monitored synchronization, the SAD did operate momentarily, but not long enough for the output relays to pick-up.

It is strongly recommended that the auto-synchronizer not be used until its performance is verified and adjusted. Figure 14 shows a manual synchronization following the 100% load rejection test. These results show a smooth synchronization and the SAD did not operate.

4.8 Recalibration prior to 75% load rejection test

Prior to performing the 75% load rejection test, the SAD was taken out of service and completely recalibrated. The offset voltage on test point 10 of each module was re-adjusted to less than 50 millivolts. These last test results showed that the calibration had remained essentially the same though one channel showed an offset of approximately 400 millivolts on test point 10.

5.0 REVISIONS TO MANUAL

Following all the revisions made to the electronic circuits, the wiring and the logic of the shaft acceleration detector, it was necessary to completely revise the manual for this equipment. The revised manual, number NA44-WAH-41170-9001-R01, was issued in June 1988 by the Power Equipment Department of D & D - Generation Division.

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Shaft acceleration detectors have now been commissioned on units 1, 2, 3 and 4 at Pickering NGS. The installation of these devices has allowed the resetting of auxiliary governors on the units to a threshold of 5% overspeed. This will remove an instability problem associated with the auxiliary governors during islanding conditions, and will contribute to maintaining the turbo-generator overspeed within safe limits following large load rejections.

It is recommended that this equipment be tested on a regular basis while the generator is on line and a more complete test be carried out during major outages. Detailed test procedures for both types of tests have been prepared and issued in Ontario Hydro Research Division report No. 88-23-K. [7]

Test points TP9 and TP10 on each Speed Detect Module must have a 10K resistor connected in series with the test point to ensure that connecting a meter or recorder lead to the test point will not cause an equipment mal-operation. Station Control Maintenance should ensure that this has been done on all units.

The dc offset voltages on test points 9 and 10 of each channel should be checked periodically and adjusted if necessary. An offset voltage on test point 10 changes the operating point of the detector.

Unit 2 should not be synchronized to the grid with the auto-synchronizer until the synchronizer has been adjusted. Its present performance results in a "rough" synchronization which can cause an SAD operation.

This report marks the end of a project which began in early 1974.

ACKNOWLEDGMENTS

The help of several staff members at Pickering NGS, both on the operations side and the commissioning group, during this commissioning work, is gratefully acknowledged.

Approved:

A. F. Baljet
Manager
Electrical Research Dept

Submitted:

R. E. Beaulieu
Unit Head - System Performance
System Studies Section, KR132
Electrical Research Dept

REB:rb

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APPENDIX

COMMISSIONING PROCEDURE FOR SHAFT ACCELERATION DETECTOR

1 General

The procedure which follows was used as a guide to commission the Shaft Acceleration Detectors (SAD) and the On-Load Test Modules. Specialized equipment is required, as outlined below.

2 Preliminary Work

2.1 Inspect all the wiring associated with the SAD to ensure that there are no visible signs of damage. In particular, check the components on the "COMPONENT BOARD" located inside the cubicle for signs of overheating resistors, etc.

2.2 Check the integrity of all leads and calibrate all the test equipment, function generator, recorder, etc.

3 Power Supply Checks

3.1 Remove fuses F2 to F22. Energize the dc power supplies and check their output voltages on the "+ve" and "-ve" test points on the speed detector modules. The levels are +26 and -26 volts dc.

3.2 If the output voltages are as per specification, open the ac supply, install all fuses for one supply and check that all the modules are energized from the one supply. Repeat with the other supply energized and the isolator of the first supply opened. Use test points TP1, TP2 and TP3 to verify the supply on each module. TP3 is common and TP1 and TP2 are +15 and -15 volts respectively.

3.3 Check that the loss of one supply causes the alarm relay to initiate AN446 for G1 and G2 or AN1002 for G3 and G4 in the Control Room.

3.4 Check that the loss of both supplies does not cause the signal to the valves to be issued (AN235 or 1003 in the control room do not come on), but an alarm (AN446 or 1002) should be given in the control room.

3.5 Energize both supplies.

4 Speed Signal Inputs

4.1 Disconnect the speed signal inputs from the three speed probes at the cubicle location (TBA terminals 61 to 66). Use a programmable function generator to simulate the speed signal.

4.2 Set the speed signal frequency at 480 Hz and verify that all the test point signals are correct. Normal values are shown below.

TP1 = +15 V POWER SUPPLY
TP2 = -15 V POWER SUPPLY
TP3 = COM OF POWER SUPPLY
TP4 = SPEED PULSE AT VERY LOW AMPLITUDE (signal on op amp junction)
TP5 = NOT USED
TP6 = N. R. SPEED TEST INPUT (0 V)
TP7 = NOT USED
TP8 = WIDE RANGE SPEED = -8.33 V
TP9 = NARROW RANGE SPEED = 0V, 12% speed deviation=10 V
TP10 = ACCELERATION = 0 V, 15%/sec=10 V

4.3 With the programmable function generator set to simulate a 5%/sec acceleration verify that the electronic modules detect this acceleration and close their output relays to initiate valve closure. It is sufficient at this stage to simply monitor the LED on the ON-LOAD test module to detect operation of the SPEED DETECT modules.

4.4 Repeat 4.3 with a 4%/sec acceleration and verify that the modules do not operate.

5 Check of the Logic

A multichannel recorder is used to record test point signals and relay operations. Contacts are monitored across terminals 40 to 55 on TBA. Refer to main schematic.

5.1 Use a three phase ac supply through a variac to simulate generator terminal voltage feeding the positive sequence filter RXTBEB4. Voltage level is 120 volts line-line under normal conditions. Voltage will be varied between 80 and 120 volts to simulate various conditions. **NOTE THAT IF THE PHASING OF THE 3-PHASE SUPPLY IS INCORRECT, THE SEQUENCE FILTER IN THE ACCELERATION DETECTOR WILL NOT BE GENERATING THE CORRECT VOLTAGE.** If the phasing is correct, the signal on TB-C, 6 & 7 will be 36 volts with 120 volts input.

5.1.1 Monitor with an ohmmeter across terminals 5 and 6 of TB-D for the operation of overcurrent relay RXIB2 contact. Vary the three-phase voltage magnitude to cause the contact to close. A voltage level of approximately 115 volts, line-line is the expected value. Now, lower the three-phase voltage until the contact opens. A level of approximately 96 volts is the expected value.

5.2 With the three-phase voltage at 120 volts, simulate an acceleration of 6%/sec for all three acceleration modules. Observe that the valve closing signal appears on TBA terminals 40 to 55, immediately the SPEED DETECT modules operate. Drawing NA44-EMG-64117-1086, revised Oct. 1987, indicates which terminals are normally opened and which ones are normally closed.

5.3 With the three-phase voltage at 80 volts, simulate an acceleration of 6%/sec for all three acceleration modules. Observe that the valve closing signal is delayed by the time setting of timer RXKB1 (approximately 125 ms).

5.4 Repeat 5.2 and 5.3 with speed detector channel one out of service. Operation should be as before.

5.5 Repeat 5.4 with channel two out of service and then channel three out of service, one at a time.

5.6 Repeat 5.2 and 5.3 with two channels out of service. No valve closing signal should be issued.

5.7 Verify that relay RL11 has the desired seal-in time to maintain the valves closed for the required amount of time. The setting is 11 seconds as of March 1988. The seal-in time is measured from the time the Speed Detector Module resets. When using a programmable function generator, the reset of TP10 is taken as time T=0.

5.8 Verify that the Remote Fault Indication operates for loss of one or more speed signals, spurious operation of one or more modules and failure of one or more power supply modules.

5.9 Verify that the SAD does in fact operate the steam valves by performing a dry test of the full logic all the way to valve actuation. **(This part is optional and is left to the discretion of the station personnel. It may be sufficient to check the signals across the blocking switches.)**

5.10 Verify that the control room RESET button causes the indicator lights on the SAD panel to reset correctly.

6 Verification of ON-LOAD Test Module

The ON-LOAD TEST MODULE contains a simple sweep generator set to provide a "speed" signal which starts at 480 Hz and sweeps upwards at the rate of 6%/second for approximately 2 to 3 seconds. It is essential that this module be calibrated during major outages to ensure that periodic on-load tests yield accurate results. The following steps will perform this calibration, using one of the SPEED DETECT module as a frequency to voltage converter.

6.1 Program the portable sweep generator for a 6%/sec acceleration, with a start frequency of 480 Hz. (Output of this generator still connected to the speed probe terminals as in 4.1 above) Initiate a sweep on the generator and record Test Point 10 of the SPEED DETECT modules on the chart recorder. Measure the amplitude of the signal on TP10 for a 6%/s acceleration. The signal should be 3 volts, $\pm$0.2 volt.

6.2 Move the CH.1 TEST SELECT switch to the ON position. Immediately this is done the CH.1 ACCN. OPER. light will come ON. Reset this light by pressing the RESET button. Now, press on the INIT. ACCN. switch downwards and hold for 3 seconds. Record Test Point 10 of the SPEED DETECT module, channel 1, on the chart recorder. Measure the amplitude of the signal on TP10 and compare to the signal measured in 6.1. The two values should be within 0.2 volt of each other.

6.3 Measure the signal on TP4 of the ON-LOAD Test Module with an oscilloscope. The signal should be a sine wave with an amplitude of approximately 6 volts peak-peak and a frequency of 480 Hz, $\pm$10 Hz.

7 Verification of Speed Probes

This part of the procedure is performed immediately following a major outage, once the generator has reached rated speed and before it is synchronized to the grid. It is important to perform this check as there is always a likelihood that the probes were damaged during the outage.

7.1 With the generator at rated speed, and the speed signals reconnected, check that the three probes deliver a signal of at least 8 volts zero-peak on TP4 of each SPEED DETECT module. Record waveforms on an oscilloscope and camera.

7.2 With the normal speed signal feeding the modules check all test points on the three modules and compare to values provided in manual.

8 Verification of Generator Terminal Voltage Signal

With the generator running on open circuit, rated speed and rated terminal voltage, measure the voltages on terminals TB-B 1, 2 and 3. The voltage should be 120 volts line-line. Measure the voltage on terminals TB-C 6 and 7. A voltage of 36 volts ac should be on these terminals.

9 Use of Auxiliary Governor

Following the initial successful commissioning of the Shaft Acceleration Detectors on all the units, the auxiliary governor was reset at approximately 5% overspeed. If it is necessary to remove the Shaft Acceleration Detector from service for a period of time in excess of thirty minutes, then the Auxiliary Governor must be reset to 2%.

10 Equipment Required

Programmable function generator with sweep function to simulate speed signal and acceleration: HP model 3314A Function Generator, or equivalent. (A combination of a Voltage-Controlled Oscillator and ramp generator can be used instead)

6-Channel direct writing recorder, Gould Model 2600S or equivalent.

3-Phase variac suitable for voltage supply available at station. (Relay panel in same room as SAD has a three phase, 120V supply)

Updated SAD manual, Number NA-44-WAH-41170-9001-R01.

Full set of drawings for the equipment and interface to governor

TABLE 1

CHECKING OF SHAFT ACCELERATION DETECTOR OUTPUTS

BLOCKING SWITCH CONTACTS	STATE WITH ACCEL. GREATER THAN 5%/s	STATE WITH ACCEL. LESS THAN 5%/s
1BS A-B	OPEN	CLOSED
1BS C-D	CLOSED	OPEN
1BS E-F	CLOSED	OPEN
1BS G-H (SAD FAULT ALARM)	CLOSED	CLOSED
1BS I-J	OPEN	CLOSED
2BS A-B	OPEN	CLOSED
2BS C-D	OPEN	CLOSED
2BS E-F	OPEN	CLOSED
2BS G-H	OPEN	CLOSED
2BS I-J	OPEN	CLOSED

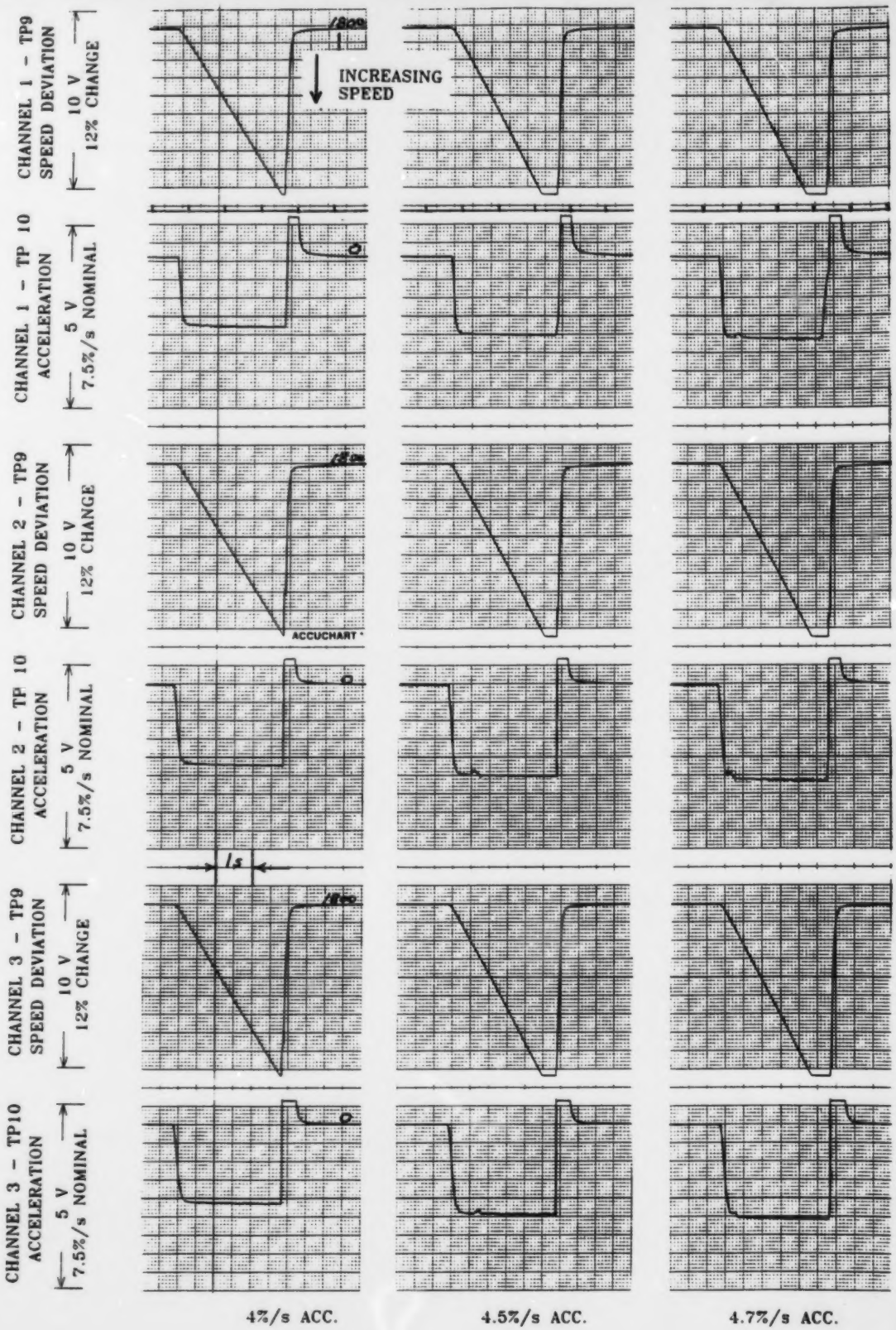

FIGURE 1
SAD COMMISSIONING RESULTS – PICKERING G2
CHANNEL CALIBRATION CHECKS

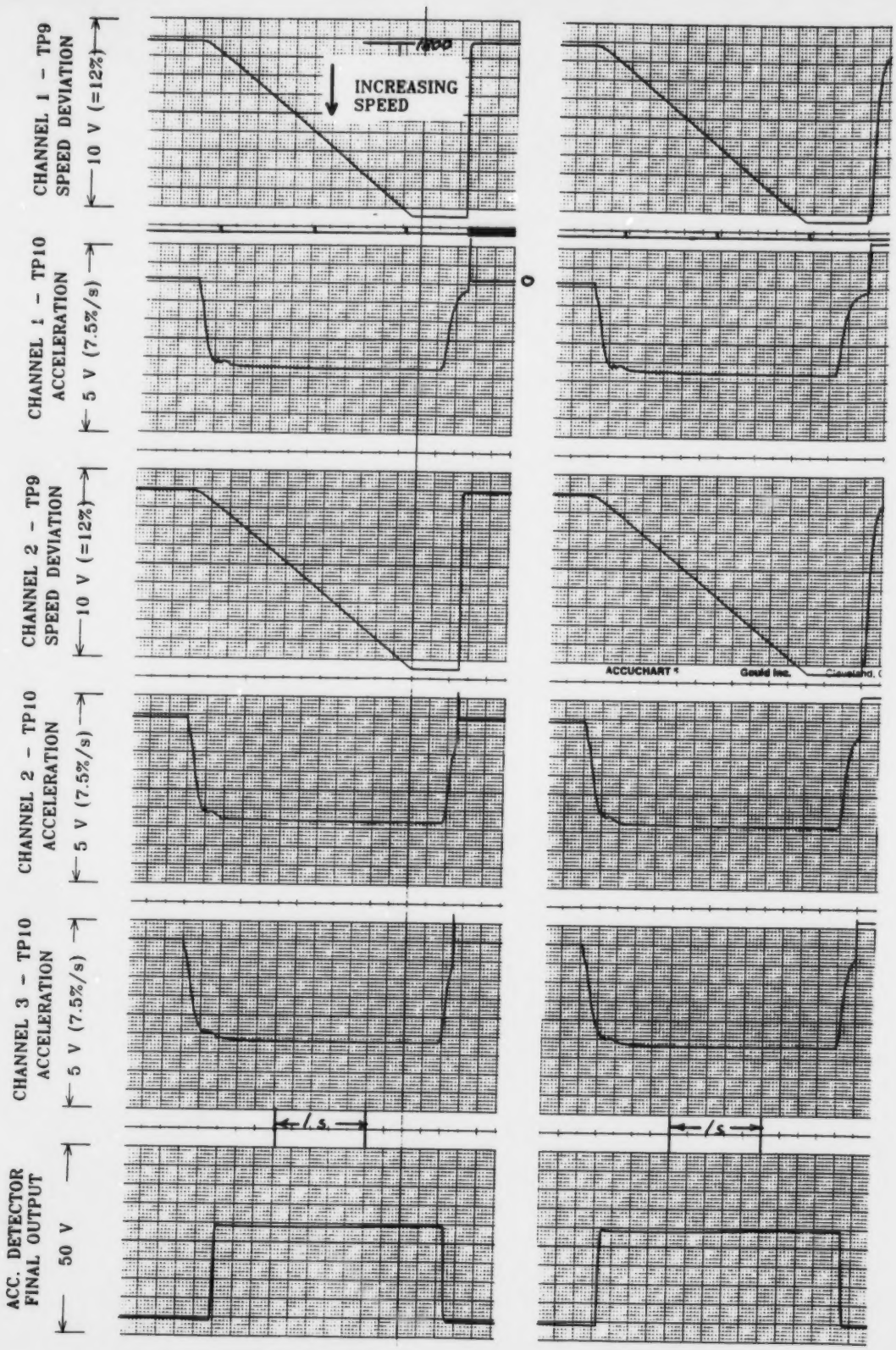

FIGURE 2
SAD COMMISSIONING RESULTS – PICKERING G2
EFFECTS OF TERMINAL VOLTAGE SIGNAL

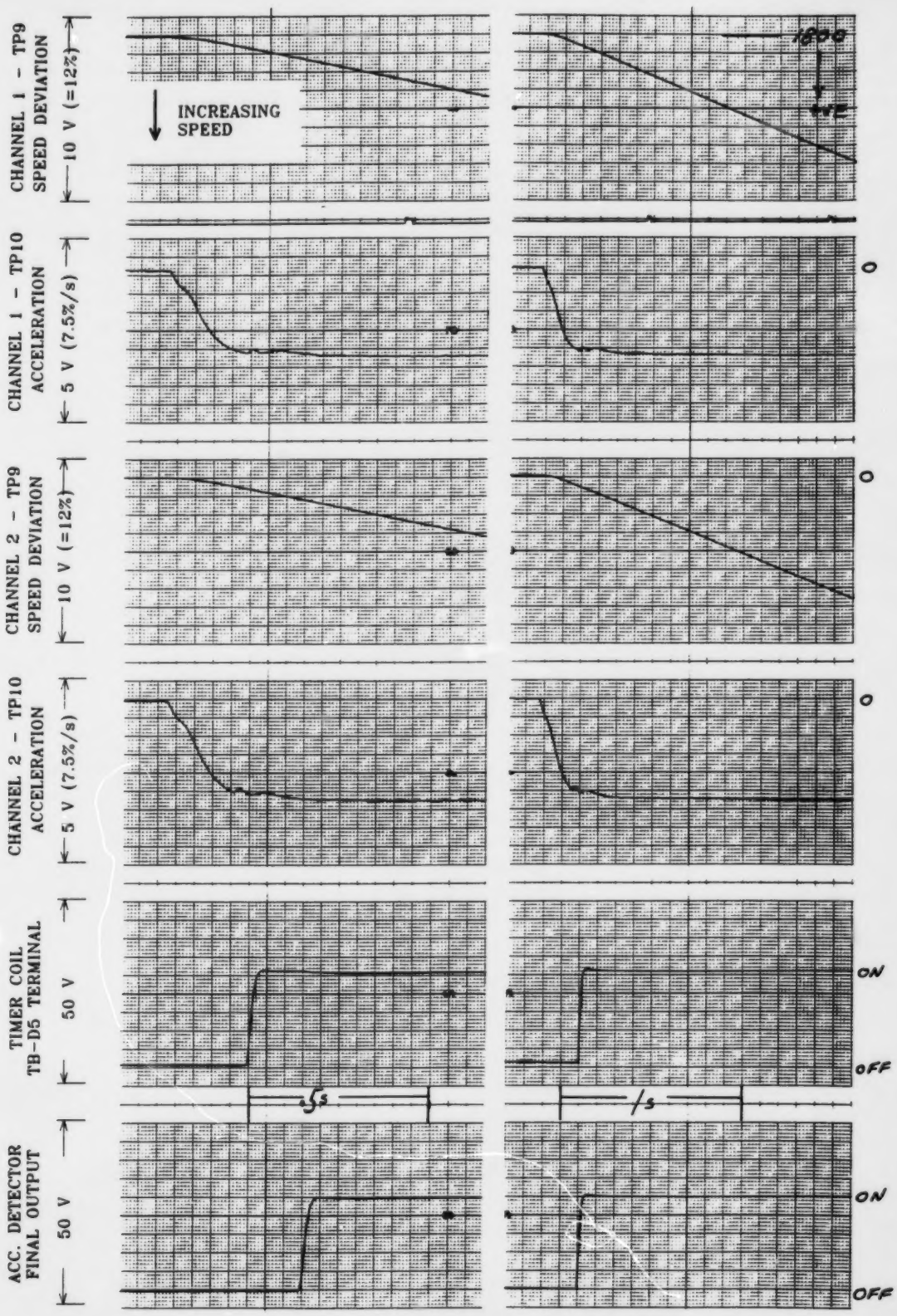

FIGURE 3
SAD COMMISSIONING RESULTS – PICKERING G2
CALIBRATION OF 150 ms TIMER

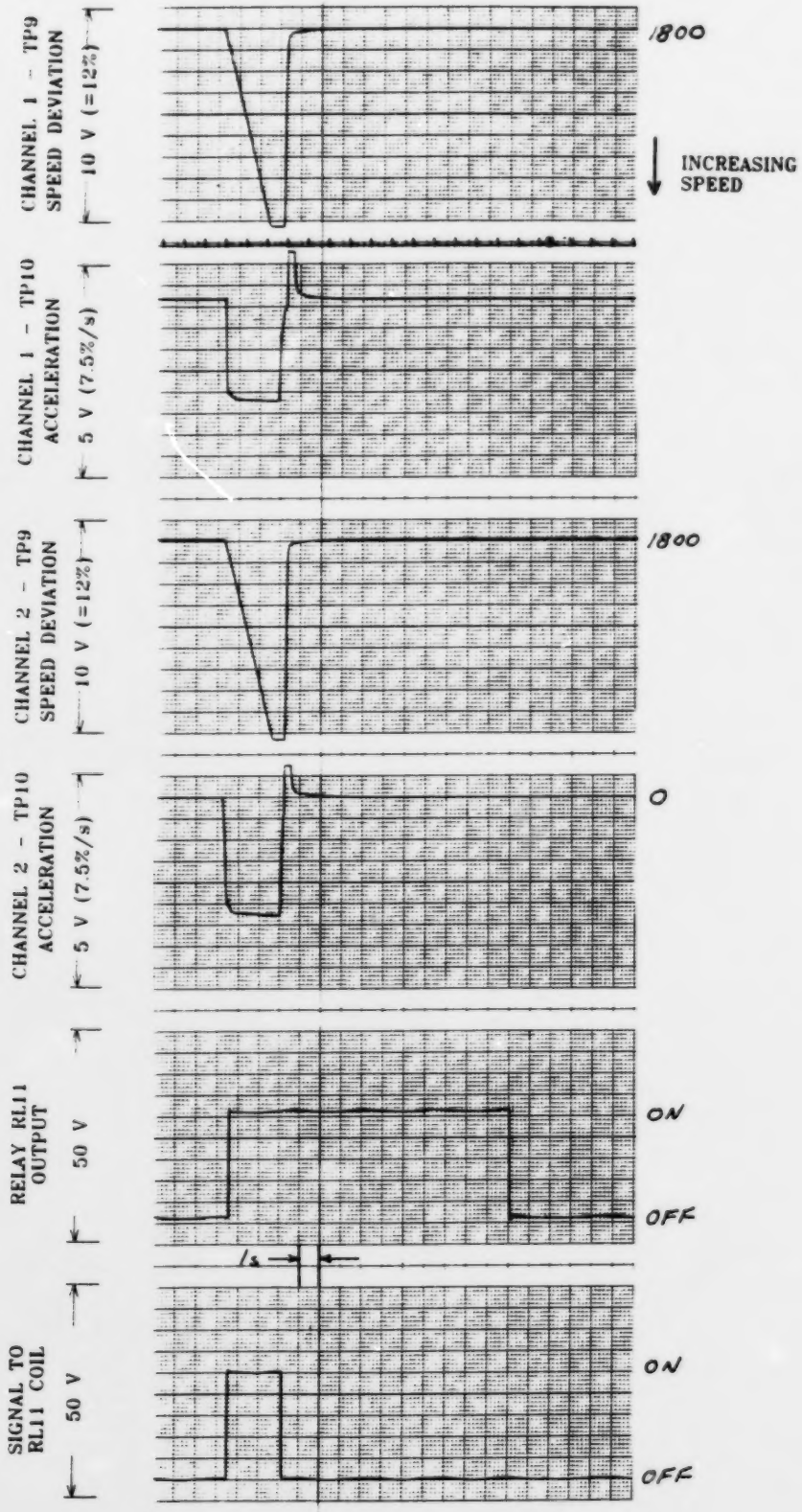

FIGURE 4
SAD COMMISSIONING RESULTS – PICKERING G2
VERIFICATION OF SEAL-IN TIMER

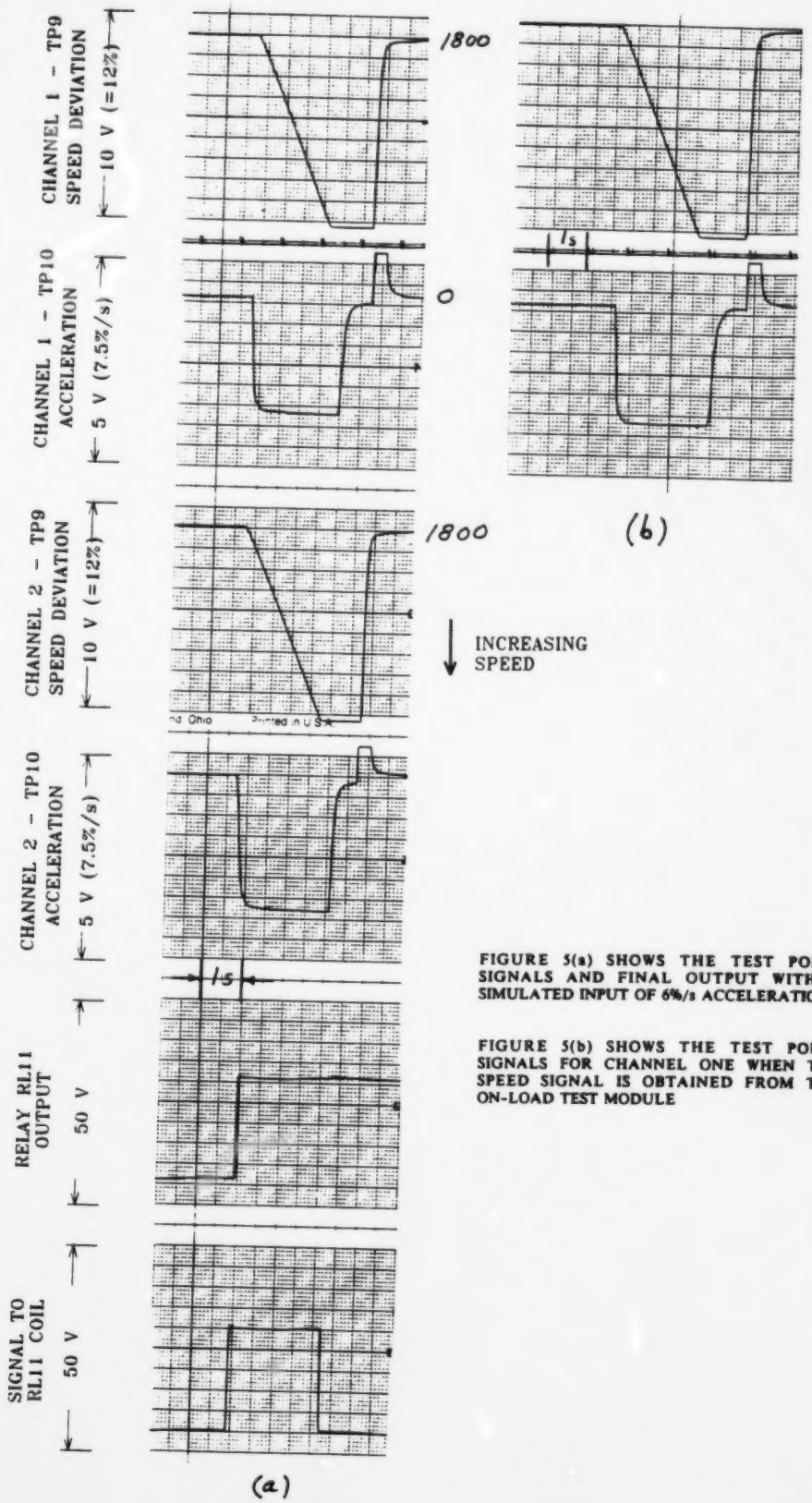

FIGURE 5(a) SHOWS THE TEST POINT SIGNALS AND FINAL OUTPUT WITH A SIMULATED INPUT OF 6%/s ACCELERATION

FIGURE 5(b) SHOWS THE TEST POINT SIGNALS FOR CHANNEL ONE WHEN THE SPEED SIGNAL IS OBTAINED FROM THE ON-LOAD TEST MODULE

FIGURE 5
SAD COMMISSIONING RESULTS – PICKERING G2
CALIBRATION OF ON-LOAD TEST MODULE

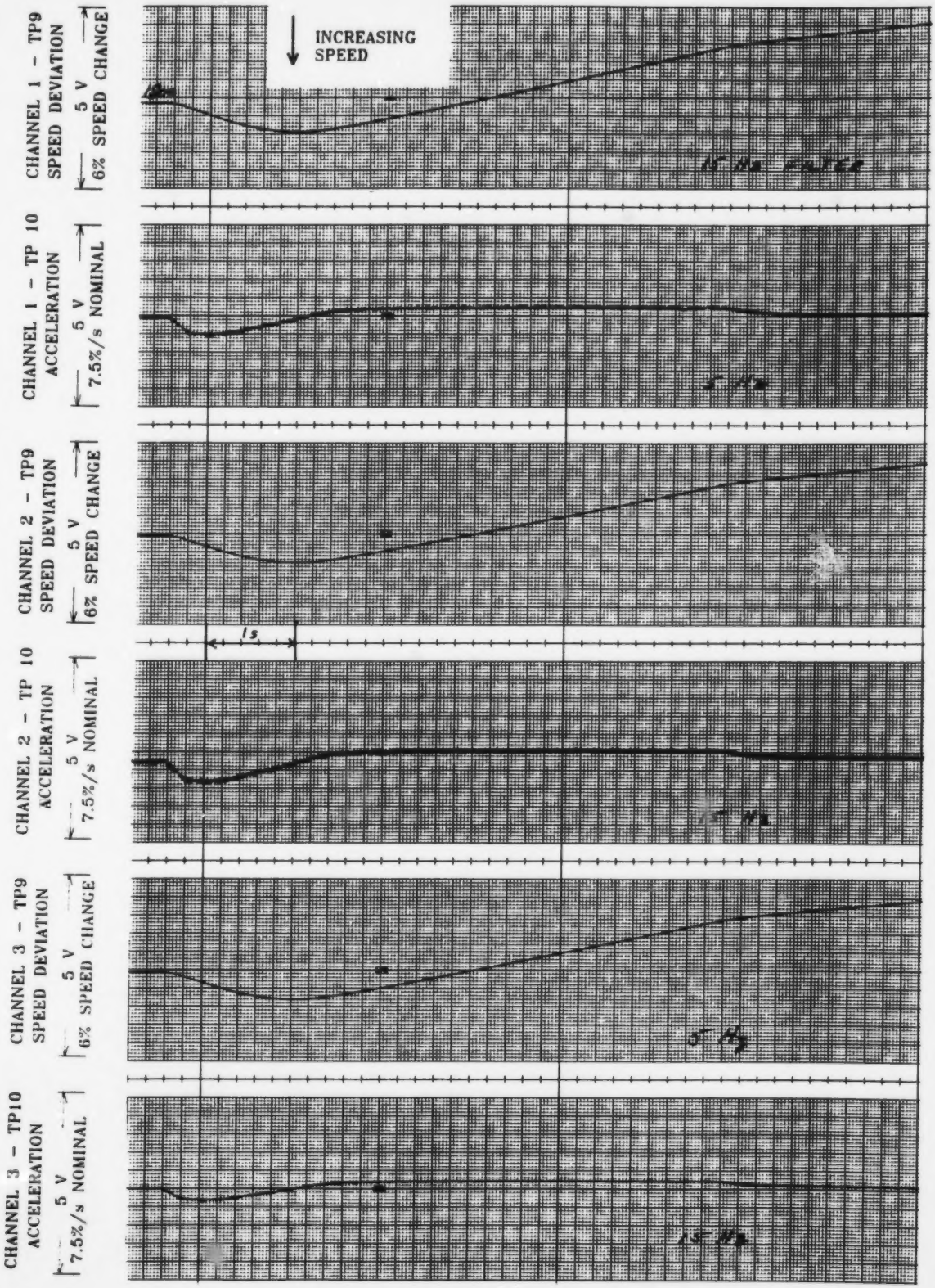

FIGURE 6
SAD COMMISSIONING RESULTS – PICKERING G2
FAILED 25% LOAD REJECTION TEST
OCTOBER 11, 1988 @ 17:48 EST

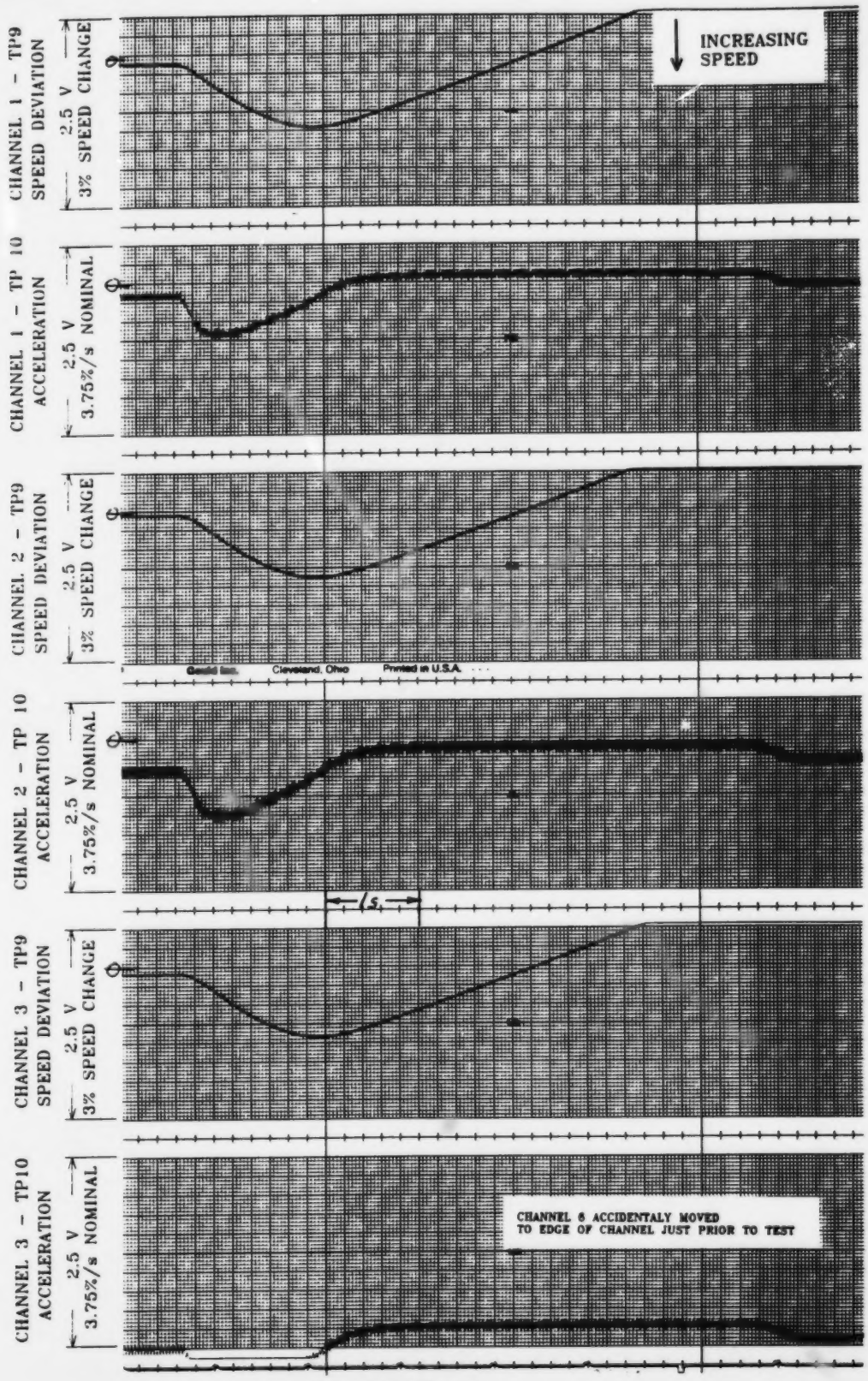

FIGURE 7
SAD COMMISSIONING RESULTS – PICKERING G2
FAILED 25% LOAD REJECTION TEST (2nd)
OCTOBER 31, 1988 @ 18:28 EST

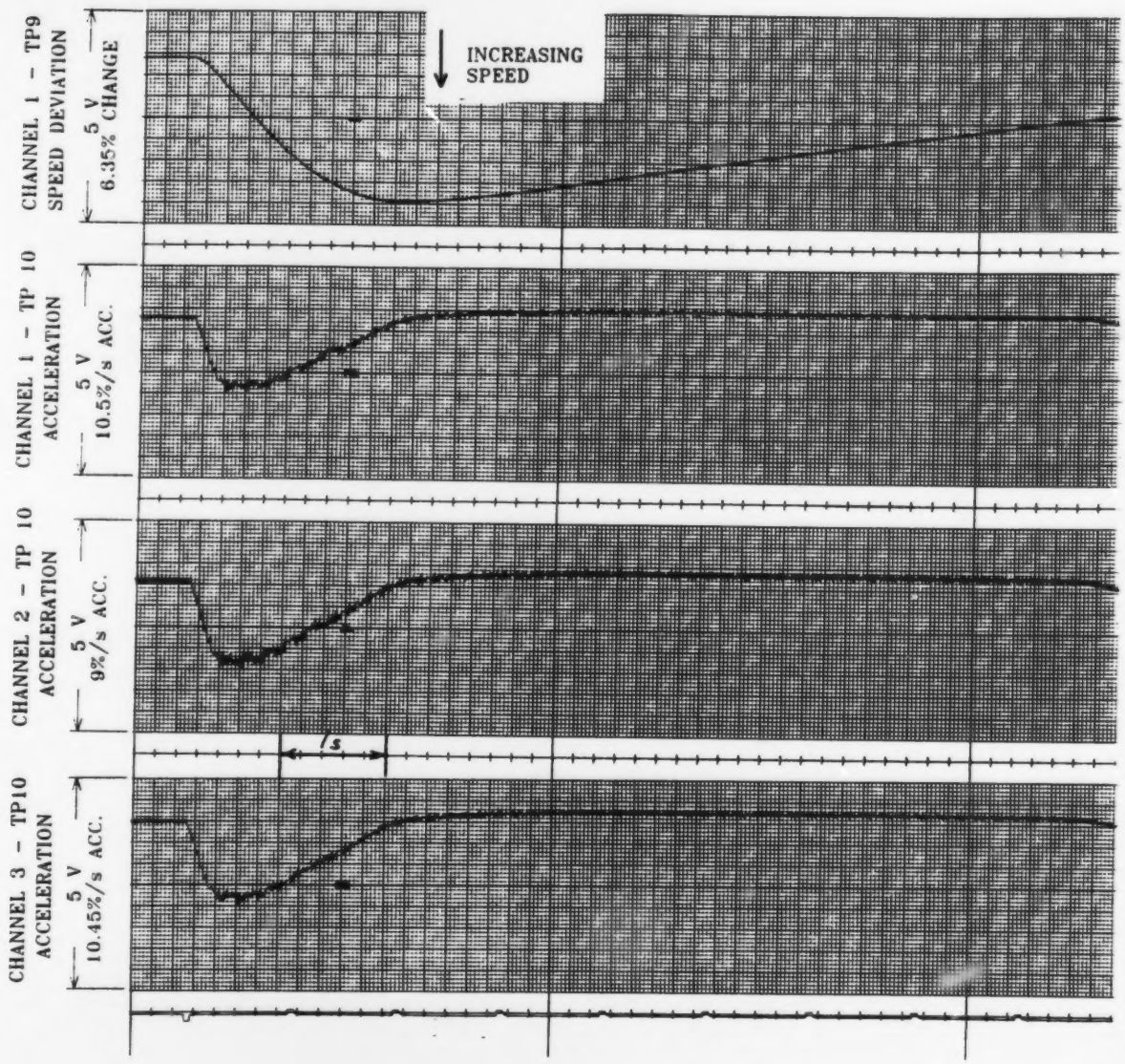

FIGURE 8
SAD COMMISSIONING RESULTS – PICKERING G2
SUCCESSFUL 50% LOAD REJECTION TEST
NOVEMBER 3, 1988 @ 21:35 EST

EADG28

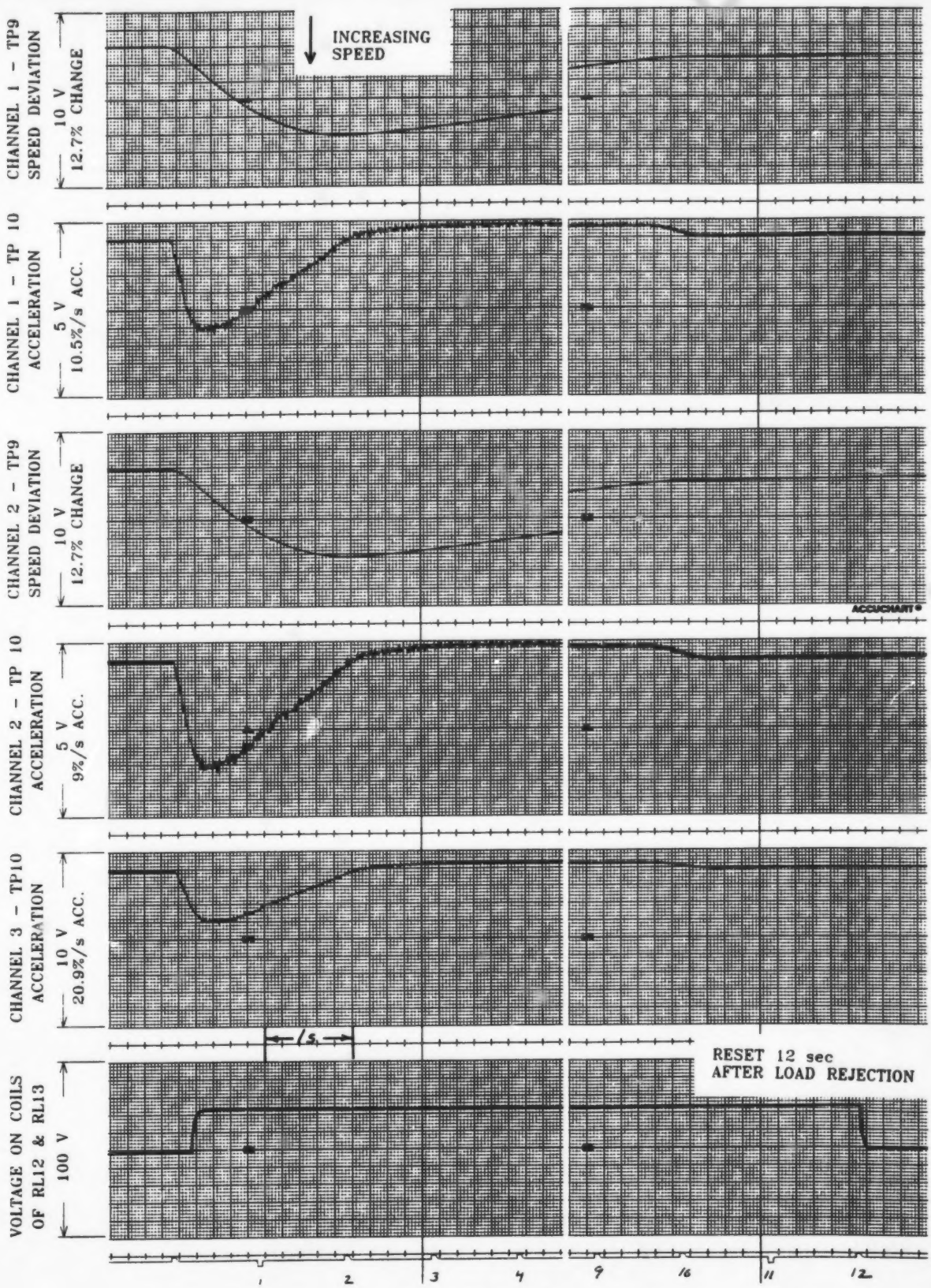

FIGURE 9
SAD COMMISSIONING RESULTS – PICKERING G2
SUCCESSFUL 75% LOAD REJECTION TEST
NOVEMBER 7, 1988 @ 03:55 EST

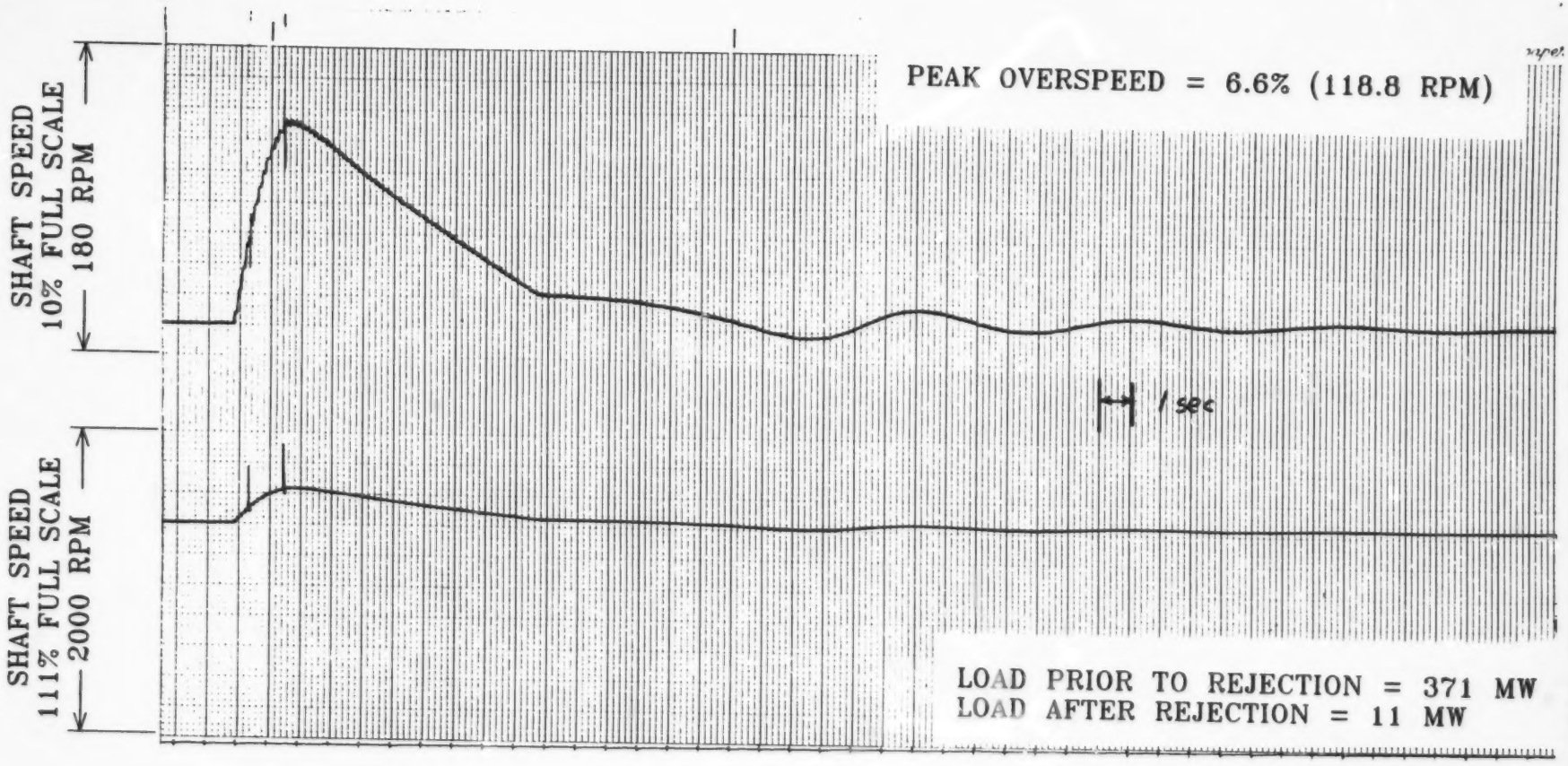

FIGURE 10
TURBO-GENERATOR SHAFT SPEED
SUCCESSFUL 75% LOAD REJECTION TEST
NOVEMBER 7, 1988 @ 03:55

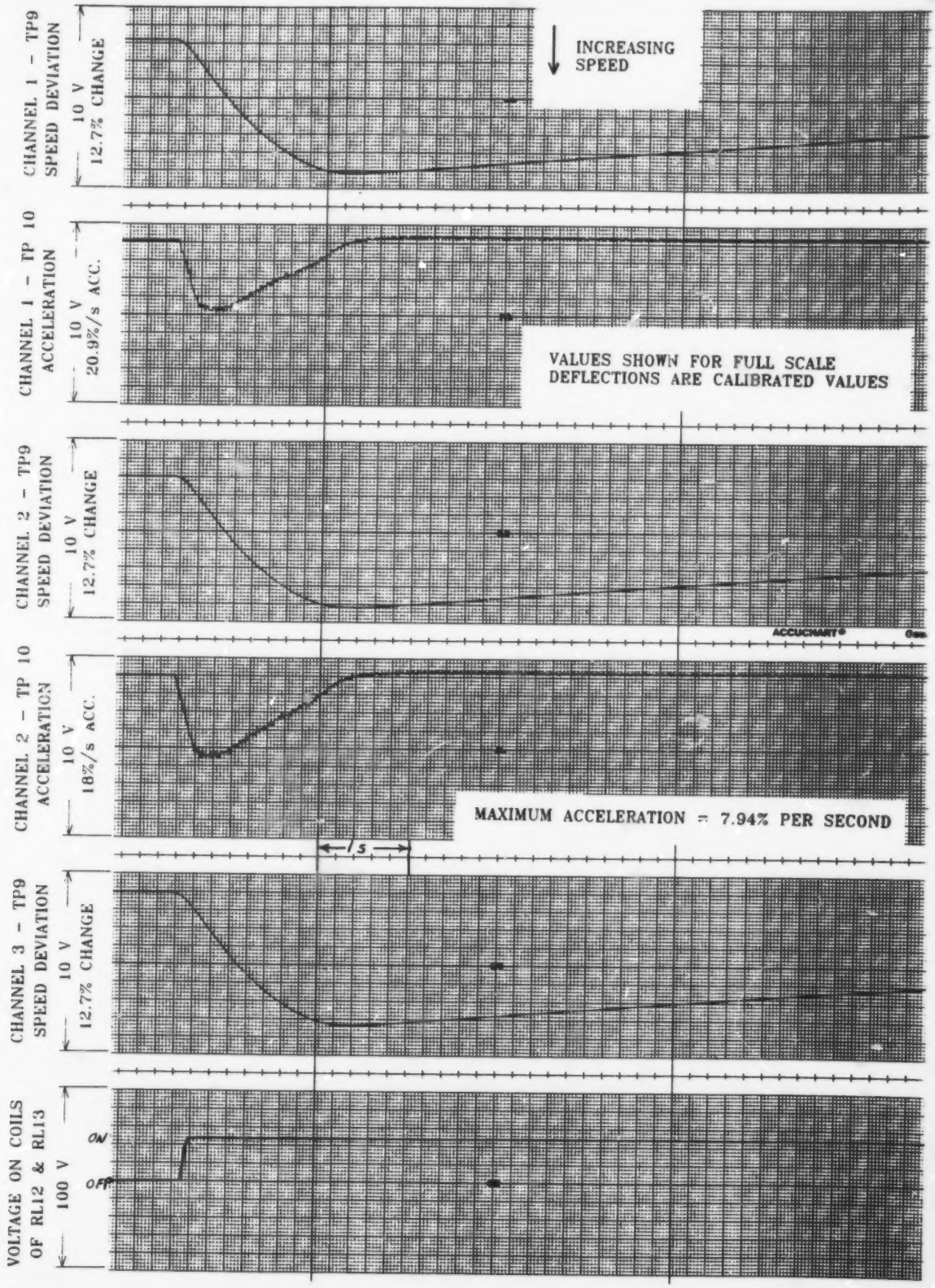

FIGURE 11
SAD COMMISSIONING RESULTS – PICKERING G2
SUCCESSFUL 100% LOAD REJECTION TEST
NOVEMBER 9, 1988 @ 06:32 EST

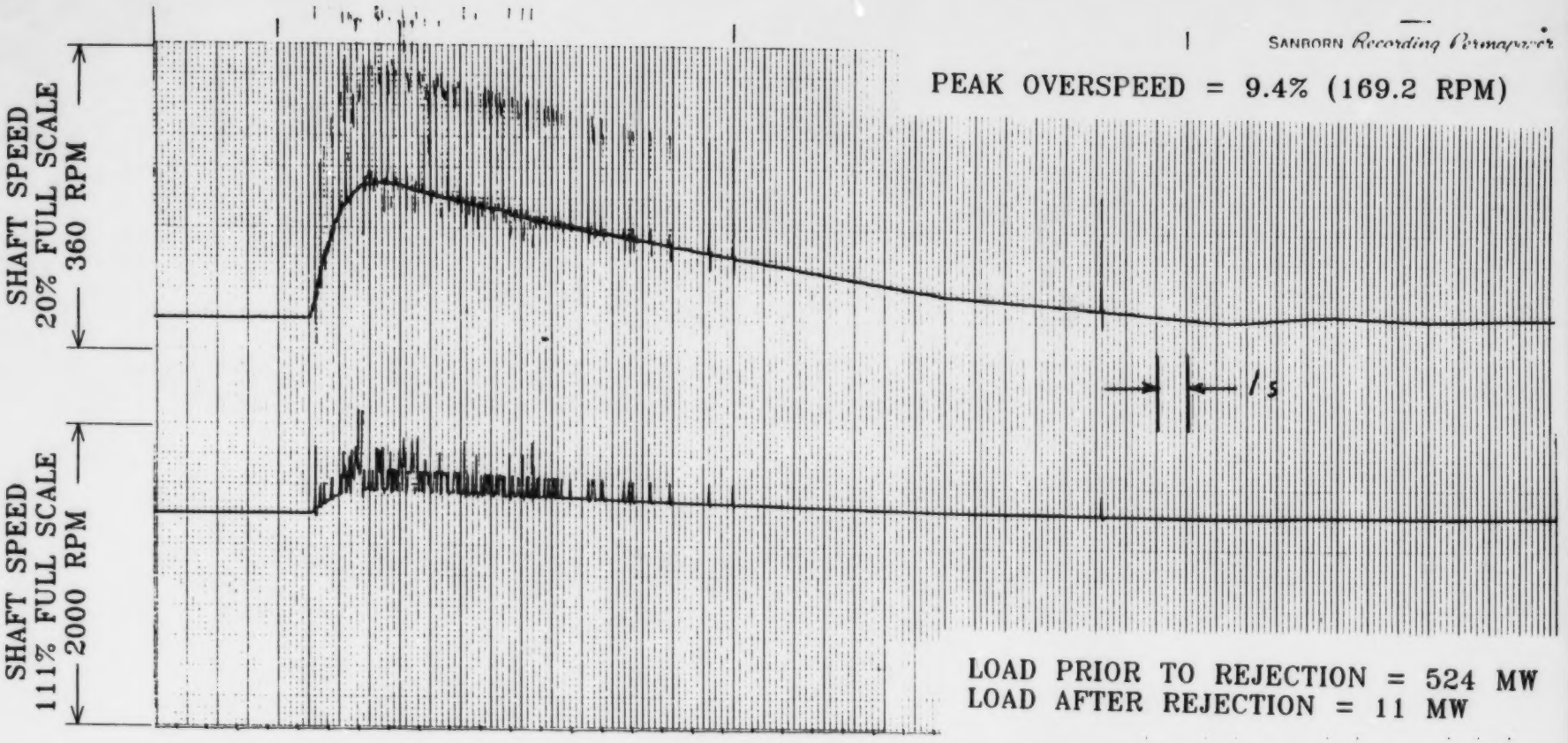

FIGURE 12
TURBO-GENERATOR SHAFT SPEED
SUCCESSFUL 100% LOAD REJECTION TEST
NOVEMBER 9, 1988 @ 06:32 EST

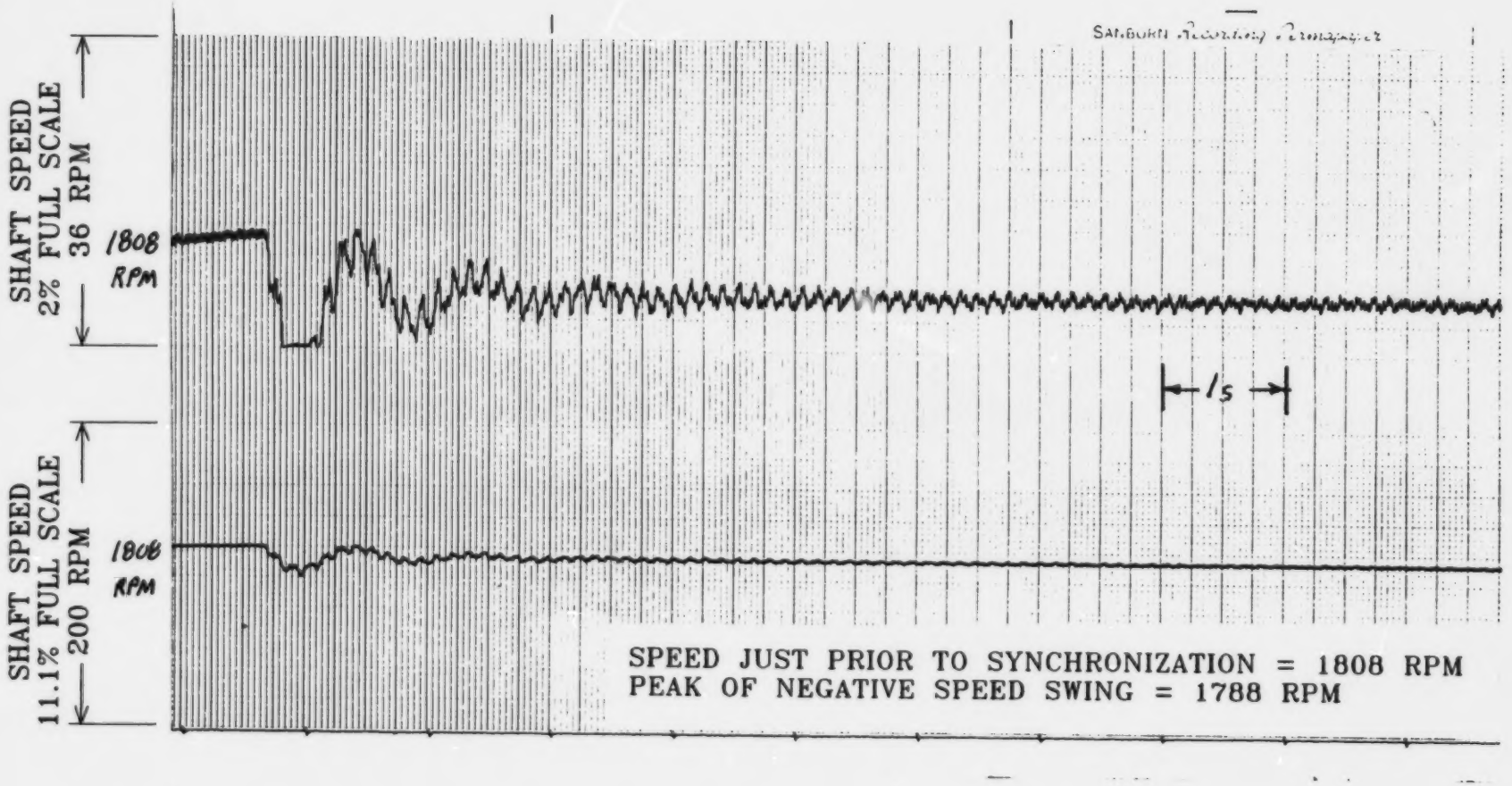

FIGURE 13
TURBO-GENERATOR SHAFT SPEED
AUTO SYNCHRONIZATION FOLLOWING 75% LOAD REJECTION
NOVEMBER 7, 1988 @ APPROX. 04:20 EST

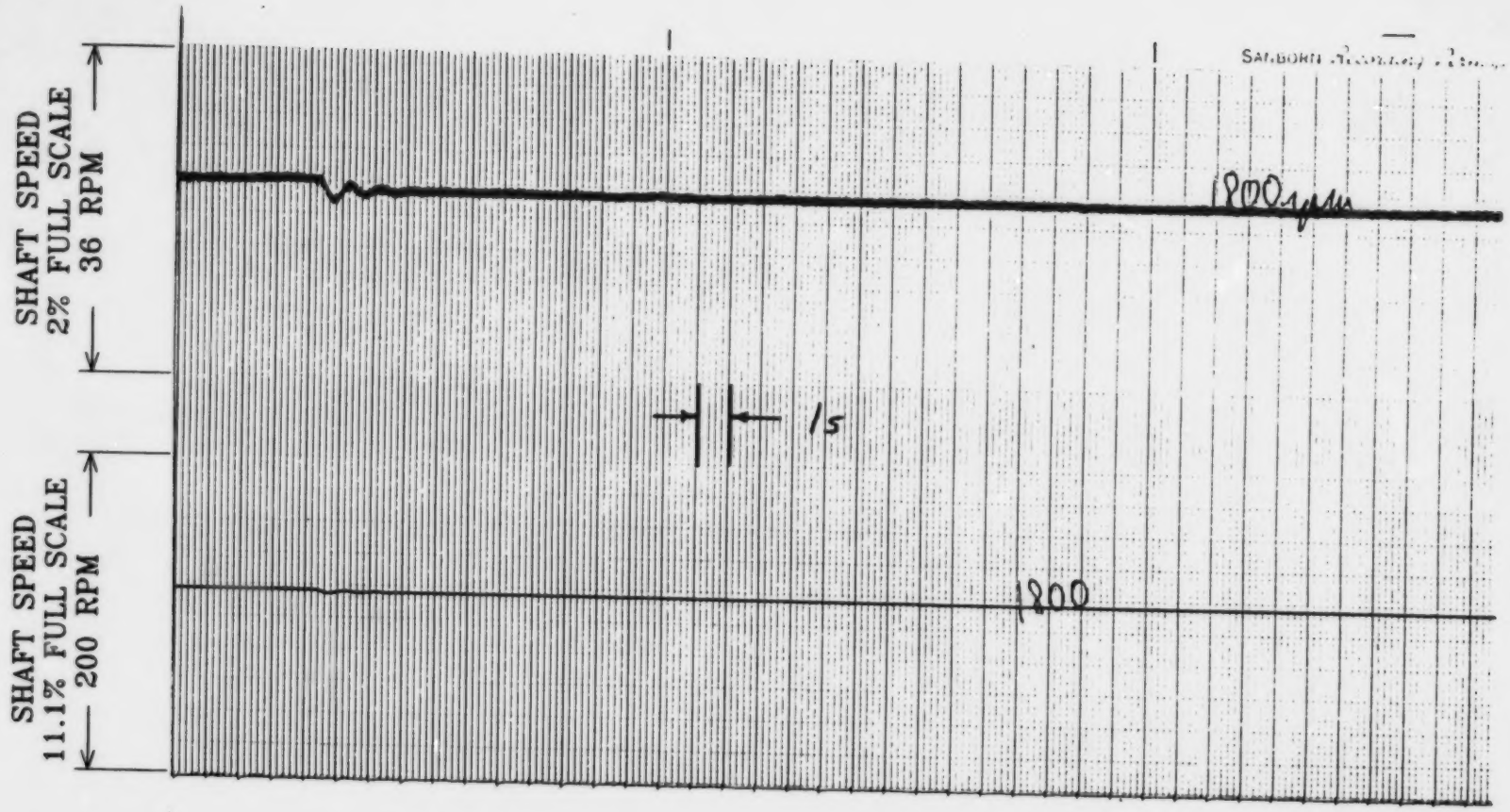

FIGURE 14
TURBO-GENERATOR SHAFT SPEED
MANUAL SYNCHRONIZATION FOLLOWING 100% LOAD REJECTION
NOVEMBER 9, 1988

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